Pain, Sports Participation, and Physical Function in Adolescents With Patellofemoral Pain and Osgood-Schlatter Disease

A Matched Cross-sectional Study

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Pain, sports participation, and physical function in 10-14 years olds with Patellofemoral Pain and Osgood Schlatter: A matched cross-sectional study of 252 adolescents

Abstract

Background: Patellofemoral pain (PFP) and Osgood Schlatter (OSD) are common in adolescents, but we lack knowledge on these conditions and their impact in young adolescents (<15 years).

Objectives: Compare pain, physical activity, quality of life, strength and knee function between adolescents with PFP or OSD, compared to pain–free controls.

Methods: Self-report questionnaires were used to describe pain, physical activity, knee function, and quality of life in participants with PFP (N=151), OSD (N=51), and pain-free controls (N=50) aged between 10 and 14 years. Hip and knee strength were measured by handheld dynamometry. Physical activity levels were measured using wearable accelerometers.

Results: More than 98% with PFP or OSD participated in sports prior to knee pain, and 60% reported reduced sports participation due to pain. Despite this, the adolescents were highly active (accumulating >120min vigorous physical activity per day), with no differences between OSD, PFP, or controls.

Adolescents with knee pain (PFP and OSD) scored 23-57 points lower than controls (P<0.001) in the Knee Osteoarthritis Outcome Score. Adolescents with OSD had lower knee extension strength compared to controls (P<0.05, effect size (ES) 1.25). In the PFP group, only females displayed lower hip abduction strength compared to female controls (P<0.05, ES 0.49). Both girls and boys with PFP had lower hip extension strength compared to controls (P<0.05, ES 0.73).

Conclusion: Adolescents with PFP or OSD are characterized by high physical activity levels, despite impaired sports participation and knee function relative to pain-free controls.

Key Terms: adolescents; musculoskeletal pain; anterior knee pain; knee function

What is known about the subject: Please state what is currently known about this subject to place your study in perspective for the reviewers.

Adolescent knee pain is common. The two most common knee complaints are Patellofemoral Pain and Osgood Schlatter. Patellofemoral pain presenting as retro or peri patellar pain in the absence of other identifiable pathologies which is aggravated by activities which load the patellofemoral joint (e.g. squatting, descending stairs). On the other hand, OSD is a traction apophysitis of the tibial tuberosity during growth, characterized by pain and swelling localized at the tibial tuberosity.

What this study adds to existing knowledge: Please state what this study adds to the existing knowledge.

Adolescents' with Patellofemoral Pain and Osgood Schlatter are characterized by impairments in sports participation, knee function and quality of life. More than 1 of 2 adolescents with PFP or OSD reduced their sports participation due to knee pain. Despite these impairments, adolescents continue with high levels of physical activity. Adolescents with PFP demonstrated reduced hip extension strength. However, only females with PFP and OSD had lower hip abduction strength compared to female controls.

Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

Introduction

Knee pain affects one in three adolescents, making it one of the most common sites of pain[1]. Persistent knee pain is associated with reduced quality of life and physical activity[2]. Perhaps due to its commonality, knee pain is sometimes considered to be self-limiting with no long-term impact. However, data indicates this does not appear to be the case, with many continuing to have pain into adulthood[3,4].

There is a four-fold increase in the years lived with disability due to musculoskeletal conditions during the transition from childhood to adolescence[5]. In the same period, there is a corresponding 8-fold increase in the number of contacts to general practice due to knee symptoms[6,7]. Approximately 6 -7% of the adolescent population are affected (with varying severity) by patellofemoral pain (PFP)[8,9], while around 10% are affected by Osgood Schlatter -also known as Osgood Schlatter Disease (OSD)[10]. Despite the high prevalence of these conditions, there is limited information regarding their impact and associated deficits in adolescents, and particularly in young adolescents. This lack of knowledge presents a barrier to developing evidence-informed treatment strategies for young adolescents with PFP and OSD. OSD is thought to be related to maturation of the tibial tuberosity with incidence peaking between ages 12 to 13[11], with the incidence of PFP is also highest during maturation[12]. Despite this, there is little data examining knee conditions in this age-group[8].

Both PFP and OSD are characterized by anterior knee pain during knee joint loading, and are aggravated by physical activity and sports participation[13,14]. PFP often has a diffuse presentation of pain around the patella, while patients with OSD experience pain localized to the tibial tuberosity[13,14]. Nearly one in two adolescents with PFP report having knee pain after five years severe enough to impact sports participation[4]. In comparison, OSD has often been described as typically lasting between 12 and 24 months with more than 90% having no residual symptoms at all[13].

Understanding differences between adolescents with PFP and OSD and their respective deficits compared to adolescents without knee pain provides information on two of the most common knee complaints in adolescents. Ultimately, this may help identify future treatment targets for these conditions.

The aim of this matched cross-sectional study is to describe potential differences in pain, physical activity, quality of life, strength and physical function in adolescents between 10 and 14 years of age diagnosed with either PFP or OSD, compared to pain free controls. Specifically, self-reported pain and function, quality of life, physical activity and hip and knee strength were assessed.

Methods

Study design

This study was designed as a cross-sectional study, embedded within two single cohort studies of PFP and OSD (NCTXXXXXXX and NCTXXXXXXX). This cross-sectional exploratory analysis compares 50 pain-free adolescents with 151 adolescents diagnosed with PFP and 51 adolescents with OSD. All three groups were recruited from local schools, social media and general practice. The study was approved by the Ethics committee of XXXXXXX (N-XXXX-XXXX) and the Data Protection Agency. All participants were required to have parental written informed consent. The study was conducted according to the Declaration of Helsinki. The reporting of the study follows the 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) statement[15]. The data included were from the two prospective cohort studies, collected at inclusion specifically for the purpose of this cross-sectional investigation. Baseline pre-treatment measures were collected when the intervention was initiated (two weeks after inclusion) and thus are not presented in the current study. The baseline data from participants with PFP are published in a prospective study investigating the effect of activity modification and load management[16]. Pain drawings (i.e. pain location) for those with PFP have been included as part of a larger study investigating pain patterns in patients from the age of 10 to 40 years of age[17].

Recruitment

Between March 2015 and April 2017 students (aged 10-14 years) from local schools were invited to answer an online questionnaire on musculoskeletal pain, including knee pain. This was supplemented by using social media to recruit adolescents with knee pain, and controls without knee pain. Potentially eligible adolescents (i.e. those reporting knee pain via the questionnaire or in response to recruitment adverts on social media) were subsequently screened by telephone and invited for a clinical examination if PFP or OSD could not be excluded by phone interview.

Participants and diagnostics

The clinical examination was conducted by one of two physiotherapists (with four and seven years of clinical experience). Diagonosis was made using a predefined set of criteria for either PFP or OSD (outlined below).

The diagnosis for PFP was made according to established recommended criteria[7,13] as follows: Insidious onset of anterior or retro-patellar knee pain for more than 6 weeks and provoked by at least two of the following positions or functions: prolonged sitting or kneeling, squatting, running, hopping or stair climbing and tenderness on palpation of the patella, or pain with stepping down or double leg squatting. In addition, participants were required to report more than 30 mm on a 100 mm Visual Analogue Scale (VAS) for worst pain experienced during the previous week.

The criteria used to diagnose OSD was in line with the literature, and included participants reporting current pain and tenderness at the tibial tuberosity, pain upon palpation of the tibial tuberosity and pain with resisted isometric knee extension[13]. Exclusion criteria for both PFP and OSD were determined through patient's medical history and clinical examination and included: Sinding-Larsen-Johansson disease, concomitant injury or pain from the hip, lumbar spine, or other structures of the knee (e.g. tendinopathy); previous knee surgery; patellofemoral instability; knee joint effusion and contraindications to MRI scan (for PFP group and included to ensure no serious pathology was missed).

Inclusion criteria for the pain-free controls were: no current self-reported musculoskeletal pain, no self-reported prior surgery in the lower extremity, no self-reported neurological or medical conditions, and no contraindications to MRI scan. Furthermore, at the time of screening controls were required to have a similar sports participation to those with knee pain to prevent differences being detected due to comparing to a population with lower levels of sports participation. The aim was to have groups that were comparable on whether or not they were sports active (yes/no) and secondly, on the approximate amount of weekly sports participation. This was done to the best of the ability of the two assessors during the telephone screening before testing. Control participants were also matched by age (age 10-14 years). The proportion of females included in the control group was targeted to be approximately between that of those with PFP and OSD, to prevent a significantly different proportion of female controls from either the PFP or OSD groups.

Data collection

The testers (XX and XX) had previous experience testing adolescents. Assessors were not blinded to status of the participant (PFP, OSD or control). Information from previous non-structured interviews with adolescents and parents informed choice of outcome domains. Based on these, limitations in sports and physical activity were considered the most important domain. Additional domains of interest were pain and knee function.

Quality of life, knee and hip strength were collected as part of the researchers' interest to inform future research and interventions. All data were collected at inclusion, before any intervention or treatment was prescribed. Groups were assessed on the following domains: physical activity and sports participation, pain symptoms, knee function, quality of life and isometric strength. All procedures were pilot tested on adolescents (with and without knee pain) before initiation of the study.

Height and weight

Bodyweight was measured using a weighing scale. Height was measured using a measurement tape taped to a wall, with participants standing against the wall in their bare feet. Body Mass Index (BMI) was calculated based on this.

Collection of self-report data

Self-report questionnaires included data on physical activity and sport, pain, function and quality of life (outlined below). If participants with PFP or OSD had bilateral pain, they were instructed to answer about their most painful knee.

Sports participation

Participants were asked to report their current sports participation (type, duration and frequency per week), and prior to onset of knee pain (PFP and OSD only). If participants had reduced or stopped sports due to knee pain, they were asked if they desired to return to their previous level of sport. Questions were piloted in a similar age group before this study to ensure comprehensibility.

Physical activity data

Objective measures of physical activity were captured by a wrist worn Actigraph GT3X+ (ActiGraph, Pensacola, FL) recording at 30 Hz. ActiGraphs are commercially available 3-axis accelerometers, validated for collecting physical activity[18]. Accelerometers such as ActiGraphs are wearable devices that measure accelerations, which are filtered and processed to obtain activity counts, i.e. accelerations due to body movement. These are used to calculate time spent in activities of differing intensities, by classifying activity counts in specific time intervals (epoch lengths) according to predefined thresholds.

Adolescents were instructed to wear the ActiGraph on the wrist of their non-dominant arm for a week after inclusion, and not to remove it unless deemed unsafe during specific activities (e.g.

taekwondo, water-polo). Data were analyzed using ActiLife, a commercially available software package. Raw data were converted into files with 10s epoch length for subsequent wear time validation and intensity classification. Non-wear time was defined as bouts of greater than or equal to 60minutes of consecutive zero counts (defined as less than or equal to 100counts/min), allowing interruptions of up to two consecutive non-zero counts (defined as 2 epochs of >100 counts per min). Adolescents were told to record the type of activity missed by the ActiGraph during non-wear. A valid day was defined as 600 valid wear-time minutes per 24 h, and four valid days required for analysis. The Evenson et al[19] cut-points were used for categorizing sedentary (0 - 100 counts/min), light (101 - 2295 counts/min), moderate (2296 - 4011 counts/min) and vigorous (4012 - ∞ counts/min) intensity physical activity, as per previous research in children and adolescents[18]. The time spent in consecutive sedentary bouts of greater than or equal to 10 mins were used to calculate average weekly sedentary time. In addition, whether or not participants met the WHO weekly physical activity recommendations (i.e. >150 mins moderate to vigorous physical activity (MVPA) or greater than 75mins vigorous activity) was calculated.

Pain and symptoms

To assess pain and symptoms, the respective subscales from the Knee Injury and Osteoarthritis Outcome Score (KOOS) were used[20]. This questionnaire was chosen as it has previously been used in young adolescents with knee pain[8,21]. Health related quality of life was measured by the youth version of the European Quality of Life 5 dimensions (EQ-5D Y)[22].

Participants also reported their worst pain in the past week on a numeric rating scale, ranging from zero to ten, from ‘no pain’ to ‘worst pain imaginable’. Pain duration was determined by the question “for how long have you experienced knee pain” (open-ended, and subsequently calculated in months).

Self-reported function and quality of life

The patient-reported questionnaire Knee Injury and Osteoarthritis Outcome Score (KOOS)[20] (adult version) which contains five separate subscales (Pain, Symptoms, Activity in Daily Living (ADL), Function in Sport and Recreation (Sport/Rec), knee-related quality of life (QoL).

Hip and knee muscle strength

Isometric knee extension strength and hip abduction strength were recorded for all adolescents. Hip extension strength was assessed in PFP and controls only. Strength was measured in the symptomatic knee or most symptomatic knee in the cases of bilateral pain. In pain-free adolescents, it was randomly chosen if right or left leg was the test leg. Three consecutive strength measurements were taken for all participants. The testing setup included a handheld dynamometer and an examination table. Muscle strength was tested using a Power Track Commander handheld dynamometer (JTech Medical, Salt Lake City, Utah), fixed to the examination bed by a belt. All strength tests were conducted isometrically and have previously been shown to be reliable[21,23]. Average force output of the three tests (Newtons) was subsequently multiplied by lever length to calculate torque, which was then normalized to bodyweight. Lever length for hip abduction was measured from anterior superior iliac spine to the position of the dynamometer at the lateral side of the lower leg, (5 cm above the lateral malleolus). Lever length for knee extension was measured as the knee joint line to the position of the dynamometer 5 cm above the medial malleolus. Lever length for hip extension was measured from trochanter major to the position of the dynamometer 5 cm above the popliteal fossa.

During knee extension, the dynamometer strap was positioned 5 cm proximal to the medial malleolus, perpendicular to the anterior or posterior aspect of the tibia. Knee extension was tested in 60 degrees of knee flexion. For hip abduction, participants were lying supine on an examination table with the leg in 0 degrees flexion and 0 degrees abduction. The strap was positioned 5 cm proximal to the medial malleolus perpendicular to the medial or lateral aspect of the tibia. Hip extension, was measured using the short lever version described by Thorborg et al[23], with a strap to fixate the dynamometer at the posterior thigh.

Participants were instructed to stabilize themselves by holding on to the sides of the examination table during strength testing. A cloth was placed between their legs and the strap from the dynamometer to reduce pain from the pressure created by the dynamometer. After receiving standardized instructions participants performed two sub-maximal practice trials. Afterwards, the individual test was administered three times, with approximately 1 minute between each test. The maximal voluntary contraction was initiated by a standardized command given by the examiner: 'Go ahead-push-push-push-push and relax' corresponding to approximately 5 seconds to ensure adequate time to generate maximal force.

Sample size considerations

No formal sample-size calculation was conducted for this cross-sectional study, as no data exists on young adolescents with PFP and OSD compared to pain-free controls. The final sample-size was a convenience sample, determined by the number of adolescents with PFP and OSD that was enrolled in one of two prospective cohort studies (NCTXXXXXXXX and NCTXXXXXXX) with the aim of investigating the clinical effect of load-management intervention in adolescents with PFP and OSD.

Statistical analysis

Data were visually inspected for approximate normality using a Q-Q plot. Mean values and standard deviations are reported for normally distributed data. Non-normally distributed data are presented as median and interquartile range (IQR). Data on physical activity and sport are described descriptively. KOOS and EQ5D scores were analyzed using a one-way analysis of variance (ANOVA) and LSD hoc test to test the difference in between groups (control vs OSD vs PFP). A two-way ANOVA was used to investigate the effect of group (control versus PFP versus OSD) and sex (male versus female) and the group * sex interaction on isometric strength measures. Effect size (ES) of the differences in isometric hip and knee strength were calculated using Cohens *d* with ES>0.80 being considered as large[24]. Sex was included in the model for strength measures due to previously documented sex-specific differences in strength[25].

Based upon peer-review comments a regression model was constructed to investigate which of the measures were most strongly associated with KOOS sport/rec. The was done using linear regression to estimate the association between sex, worst pain last week, isometric strength, diagnosis and KOOS sport/rec. Univariable analyses were initially performed and variables of P<0.15 in the univariable analyses were included in the multi-variable model[26]. A separate regression model was also developed for the PFP group only to allow for the inclusion hip extension strength data. All calculations were performed using Stata version 11 (StataCorp, College Station, Texas, USA) and SPSS v. 21 (IBM Corp, Armonk, New York, USA). Significance was accepted for P-values less than 0.05.

Results

Demographics

Two hundred and fifty-two adolescents (151 with PFP, 51 with OSD and 50 pain-free controls) age 10 and 14 years were recruited and tested (Figure 1). We assessed 85 controls for eligibility, of which 35 were excluded: 34 due to not being a match, and 1 for reporting knee pain during phone screening.

Age was similar across the three groups (Table 1). One third of those with knee pain had previously received treatment for knee pain. The reported treatments were: treatment by physiotherapist (14/51), acupuncture (3/51) and shockwave (2/51) in those with OSD, and treatment by physiotherapist (34/151), acupuncture (4/151) and painkillers (2/151), in adolescents with PFP.

Sports participation and objective physical activity

Almost all adolescents with PFP and OSD reported participating in sports prior to onset of their knee pain (98% and 100%, respectively). More than 50% reported reducing their sports participation, with the most common causes being “pain” and “I am afraid to damage my knee”. Nine percent of adolescents with PFP reported a complete stop of sports due to knee pain, compared with 26% of adolescents with OSD. All adolescents except one had a desire to return to sport (Table 2). Using objective measure of physical activity from the ActiGraphs, there were no differences between groups in average time spent in sedentary, light, moderate or vigorous physical activity (Table 2). (Based on ActiGraph data from 132 with PFP; 36 with OSD and 48 controls. Loss of data due to ActiGraph malfunctioning / data could not be properly extracted from the device/excluded due to non-wear-time).

Pain and symptoms

Adolescents with PFP and OSD reported pain for an average of 21 months. Pain and symptoms are reported in Table 3.

Function and quality of life

There was a significant difference between groups for KOOS ADL (F= 55; p <0.001), KOOS sport and recreation (F=52; p<0.001) and KOOS quality of life (F= 217; p<0.001). Post hoc pairwise comparisons revealed adolescents with OSD or PFP were lower than pain free controls (P<0.001; mean differences in Table 4). Adolescents with OSD had significantly lower KOOS Scores compared to adolescents with PFP in quality of life domain (P<0.05) (Table 4) but not in ADL or sport/rec domains (p>0.05).

EQ 5D scores were significantly different between groups (F=56; p<0.001). Compared to controls, the EQ 5D index score was significantly lower in both the PFP (mean difference = 0.38, 95% CI 0.31 to 0.45; p<0.001) and OSD (mean difference = 0.37, 95% CI 0.28 to 0.46; p<0.001)) groups (Table 4). There was no difference between OSD and PFP groups (p=0.762; Table 4).

There was a significant sex*group interaction for hip abduction strength ((F=3.9); p=0.02), Post hoc testing revealed a simple main effect of group on hip abduction scores which was statistically significant for females (F=7.7; p=0.001) but not males. Compared to control females, hip abduction strength was significantly lower for females with OSD (mean difference = 0.41, 95%CI 0.20 to 0.61;

p<0.001, ES 1.16 95%CI 0.57-1.73; Figure 2) and PFP (mean difference =0.21, 95% CI 0.06 to 0.36, p<0.01, ES 0.49 95%CI 0.08-0.88) with no differences between males (p=0.398).

For knee extension strength, there was not a significant interaction (p>0.05), but there was a significant main effect for group (F= 19; p<0.001). The group with OSD had significantly reduced knee extension strength compared to controls (mean difference =0.65, 95% CI 0.39 to 0.92 p<0.001, ES 1.25 95%CI 0.82-1.68) and those with PFP (mean difference = 0.65, 95% CI = 0.43 to 0.87; p<0.001, ES 0.99 95%CI 0.64-1.32; Figure 2). There were no differences between PFP and controls for knee extension strength (p=0.986).

For hip extension strength, there was no sex * group interaction. There was significant difference between groups, with lower strength in the PFP group compared to controls ((F=17; p<0.001; mean difference =0.36, 95% CI 0.18 to 0.53, ES: 0.73 95% CI 0.40-1.05; Figure 2).

Factors associated with KOOS sport/rec

In the univariable analyses, higher knee extension torque was associated with higher KOOS sport/rec, while higher ‘worst pain in the past week’ was significantly associated with lower KOOS sport/rec (Table 5a). After adjustment in the multivariable model, higher ‘worst pain in the past week’ and OSD diagnosis remained significantly associated with lower KOOS Sport/Rec Scores. Knee extension torque was not significantly associated with KOOS Sport/Rec in the multivariable model (Table 5a).

When examining PFP only, univariable analyses indicated sex, hip extension torque, and ‘worst pain in the past week’ were associated with KOOS sport/rec scores (Table 5b). Female sex, higher ‘worst pain in the past week’, and lower hip extension torque were associated with lower KOOS sport/rec scores in the PFP group. Except sex, these associations remained significant in the multivariable model. Table 5a and 5b demonstrate the unadjusted coefficients from the univariable models, as well as the adjusted coefficients and p-values for the variables which remained significant in the multivariable model after accounting for other factors.

Discussion

This is the first cross-sectional study to characterize pain, physical activity and knee function in 10-14-year-old adolescents diagnosed with PFP and OSD. This study demonstrates that these two common knee pain complaints in young adolescents (PFP and OSD) impact pain, self-reported sports participation, physical function and quality of life. While participants reported having to stop or reduce sport due to knee pain, the ActiGraph data demonstrate that the participants were still very physically active, accumulating approximately two hours of vigorous physical activity (e.g. jogging, fast bicycling, or a soccer game) per day. Strength deficits were identified between groups, but sex was not a factor in the relative hip extension strength deficits identified in PFP. Regardless of sex, adolescents with PFP demonstrated reduced hip extension strength compared to pain free controls, however only females (with PFP and OSD) had lower hip abduction strength compared to female controls. Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

Despite the young age of the participants, the impact of pain on sports and physical function is similar to what has been seen in older adolescents with PFP (aged 15 - 19 years)[8]. Almost all adolescents reported participating in sport prior to the onset of their knee pain, and the majority reduced their participation due to pain. In contrast, in older adolescents with PFP, only two out of three adolescents with PFP participated in sports[8]. As older adolescents with PFP also reported a longer duration of symptoms, this may explain the differences in sports participation.

In this study, one in every four adolescents with PFP used painkillers. Interestingly, use of pain medication among adolescents with OSD was half this, despite worse symptoms and larger reductions in sports participation due to pain. The reason for the difference between the populations is unclear, and may warrant further examination.

In PFP, higher hip extension torque was associated with higher KOOS sport/rec scores. Hip abduction torque was not associated with KOOS sport/rec scores. A recent systematic review including both adolescents and adults, highlighted that low hip muscle strength may be a consequence of PFP, rather than the cause[25]. Interestingly, a previous smaller study found no difference in quadriceps strength between kids between the age of 11 and 18 with OSD compared to 13-year-old soccer players. However, this group was not matched on age and there were no mentioning of sex, height, weight or other patient demographics making a comparison to the current study difficult[27]. The current data show large deficits in knee extension torque for those with OSD. Interestingly females with OSD also displayed significant hip abduction strength deficits. While knee extension torque was significantly associated with KOOS sport/rec subscale, this relationship did not exist in the multivariable model after accounting for diagnosis (PFP or OSD). Further, there was no relationship between knee extension strength and KOOS Sport/Rec scores in the model examining only PFP. Despite we can’t infer cause and effect in this population (i.e. if the changes are prior or subsequent to knee pain), knee and hip strengthening exercises may be worth considering as part of management to improve function and performance to help ensure the adolescent return to sport without large strength deficits. Rest, stretching, or other passive modalities are unlikely to improve the knee extension strength, or hip abduction strength for females with OSD[10,13,28].

Both PFP and OSD are considered overuse musculoskeletal pain complaints caused by exposure to high repetitive loads[29 13]. Despite the pain and significant self-reported difficulties on KOOS Sport/Rec, the majority of adolescents with PFP and OSD continued to participate in physical activity. Our results indicate that despite their knee pain, both PFP and OSD were as physically active as the controls, even after reporting that they had decreased their sports participation as a result of knee pain. On average they accumulated more than 2 hours of vigorous activity per day, which is four times the average of the International Children’s Accelerometry Database (ICAD)[30]. They accumulated more than four hours of MVPA per day, which is 6-8 times as much as the average in the ICAD and twice as much a male players aged 10–14 who participate in grassroots football in three European countries[31]. Adolescents reported participating in sports 3-4 times per week. This does not account for all the objectively measured vigorous activity, suggesting these adolescents also participate in a lot of vigorous activity during school and leisure time.

Importantly, this which needs further understanding as it might continue to aggravate their knee pain. More research is needed to understand if continued sports participation should be advised, or if it will impede recovery through persistent loading of their painful knee. Early specialization in a single sport has been shown to be associated with an increased risk of suffering from PFP, OSD and Sinding Larsen Johansson/ patellar tendinopathy in adolescent girls[32]. This is likely due to repetitive sports specific loading, with OSD demonstrating a 4-fold greater relative risk in single-sport compared with multisport athletes[32]. The challenge for this population may be to find the type and right amount of physical activity and sport that will keep the adolescents active without aggravating their knee pain or hampering long-term recovery. Modifying or changing loading on specific structures may be a relevant target for future treatments in this population.

Clinical implications

In adolescents with OSD, we found large strength deficits in knee extension, which may suggest a rationale for including knee extension strengthening in this group of adolescents (if the desired outcome is to improve muscular function and performance). Recommendations for OSD are diverse but often include rest, stretching and return to sports after pain has settled, despite a lack of evidence supporting this recommendation[13]. Based upon the desire of return to sport, and high activity despite long-standing knee pain, future research is needed to develop load management and return to sport algorithms for both of these populations.

Limitations

The two assessors were not blinded to which adolescents suffered from PFP, OSD or who were pain-free controls. This may increase the risk of detection bias and increase potential between-group differences. However, the main conclusion on the severe impact of PFP and OSD is unlikely to be affected by the lack of blinding affected. As hip extension was not collected in OSD we cannot evaluate whether hip extension strength deficits exist in adolescents with OSD. There smaller group numbers when stratifying by sex may have made it difficult to detect sex differences in strength. Further, we did not assess biomechanics which could provide information regarding distinguishing features of these two patient populations. The use of the KOOS adult version is a potential limitation, as this is not validated for this patient population. As this is a cross-sectional study, strong conclusions on clinical implications cannot be drawn, and thus suggestions are speculative based on the observations in the current study.

Conclusion

Ten-to-14-year-old adolescents with PFP or OSD are characterized by high levels of vigorous physical activity even in the presence of long-standing knee pain. They report difficulties with sports participation and impaired knee function, relative to pain-free controls. Clinicians treating adolescents with PFP or OSD may use these findings to target treatment to the most common deficits to restore sports-related function and sports participation.

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Tables and Figures

Table 1: Demographics. (Data are reported as mean (SD) or percentages for count data, unless otherwise stated).

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)
Age [years]	12.6 (1.2)	12.7 (1.1)	12.3 (1.4)
Gender (% females)	76%	51%	62%
Weight [kg]	50.4 (9.4)	55.8 (10.1)	48.0 (10.4)
Height [cm]	162.0 (9.6)	165.5 (8.4)	159.8 (10.5)
BMI (Interquartile range)	19.0 (17.2-20.8)	20.2 (17.6-22.0)	18.0 (17.1-20.0)
Previously treated for knee pain (% who replied yes)	28%	37%	N/A
Pain medication for knee pain (% who replied yes)	24%	12%	0%
Current sports participation (% who participated in leisure time sports)	91%	74%	88%

Table 2: Sports participation and physical activity levels

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)
Did you participate in sport before onset of knee pain? (% who replied yes)	98%	100%	N/A
Competitive sport before onset of knee pain? (% playing competitive sport)	55%	49%	N/A
Did you reduce the amount of sports participation because of your knee pain? (% who replied yes)	64%	49%	N/A
If you don´t participate in sport currently, do you desire to return to sport? (% who replied yes)	100%	98%	N/A
How many times per week do you currently participate in sport (training + competition per week)? *	3 (2-5)	4 (3-5)	3 (1-4.5)
Physical activity levels [measured with ActiGraph]*			
Sedentary [min]	346.6 (333.8-359.4)	344.2 (330.3-358.1)	353.9 (330.3-377.6)
Average light [min]	334.0 (326.8-341.2)	333.8 (315.7-351.9)	318.0 (304.0-331.9)
Average moderate [min]	113.1 (109.2-116.9)	115.5 (106.4-124.6)	109.0 (102.2-115.7)
Average vigorous [min]	127.4 (120.0-134.8)	133.1 (117.5-148.7)	142.5 (128.0-157.0)
Mod to vigorous physical activity (MVPA)	240.5 (229.9-252.1)	248.7 (225.1-272.2)	251.5 (231.3-271.7)
% reaching WHO minimum PA per day	94.7%	91.7%	91.7%

*Based on ActiGraph data from 132 with PFP; 36 with OSD and 48 controls. ActiGraph data reported as mean (95% CI) minutes per day.

Table 3: Pain and symptoms

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)	Mean diff PFP v Ctrl (95%CI)	Mean diff OSD v Ctrl (95%CI)	Mean diff PFP v OSD (95% CI)
Age when knee pain started[$] [years]	11 (10-12)	11 (10-12)	N/A			

Average pain duration (months)	21.3 (17.0)	20.8 (12.5)	N/A			0.5 (-4.7 to 5.7)
Duration of symptoms (n (%))*						
3-6 months	6 (4%)	4 (8%)	N/A			
6-12 months	31 (22%)	2 (4%)	N/A			
>12 months	107 (74%)	44 (88%)	N/A			
Bilateral pain (% who replied yes)	73.5%	71.4%	N/A			2.1 (-12.3 to 16.5))
Worst pain last week (NRS)	6.5 (2.0)	6.4 (2.3)	0			0.1 (-0.6 to 0.8)
KOOS$_{pain}$ [0-100, worst to best]	66 (63-70)	67 (63-68)	100 (100-100)	-22 (-18 to -26)	-26 (-21 to -31)	4 (0 to 8)
KOOS$_{symptoms}$ [0-100, worst to best]	77 (75-80)	73 (69-78)	98 (96-99)	-32 (-28 to -37)	-31 (-26 to -37)	-1 (-5 to 3)

Values presented as mean (SD) except age when knee pain started and percentage with bilateral pain.
$ median and interquartile range
* 1 with OSD and 7 with PFP were not able to remember when their knee pain started and did not respond to the question

PFP: Patellofemoral pain; OSD: Osgood Schlatter; NRS: Numeric rating scale; KOOS: Knee Injury and Osteoarthritis Outcome Score.

Table 4: Knee Injury and Osteoarthritis Outcome Score (ADL, Sport; QOL) and EuroQoL 5D-3L

	Patellofemoral Pain (N=151)	Osgood Schlatter (N=51)	Pain free controls (N=50)	Mean diff PFP v Ctrl (95%CI)	Mean diff OSD v Ctrl (95%CI)	Mean diff PFP v OSD (95% CI)
KOOS$_{ADL}$ [0-100, worst to best]	77 (75-80) †	78 (75-82) †	100 (100-100)	-23 (-19 to -27)	-22 (-19 to -27)	-1 (-3 to 6)
KOOS$_{Sport/rec}$ [0-100, worst to best]	54 (50-58) †	43 (37-49) †	100 (100-100)	-48 (-38 to -58)	-56 (-44 to -68)	8 (-2 to 18)
KOOS$_{QOL}$ [0-100, worst to best]	50 (47-53) †#	44 (39-48) †	100 (100-100)	-50 (-45 to -55)	-56 (-50 to -62)	6 (1 to 11)
EuroQol 5D 3L* [index score]	0.72 (0.63-0.78) †	0.72 (0.44-0.78) †	1 (1-1)	-0.38 (-0.31 to -0.45)	- 0.38 (-0.28 to -0.45)	-0.01 (-0.08 to 0.06)

*Presented as median and interquartile range
† Significantly different from control
# Significantly different from OSD

Isometric muscle strength

Table 5a and 5b: Univariable and multivariable models testing the association between worst pain in the last week, strength, diagnosis and KOOS sport/rec

Model 1: Association with KOOS sport/rec among all with knee pain	Unadjusted coefficient from univariable analysis	p-value	Adjusted coefficient	p-value Adj coefficient
Knee extension torque	4.6 (0.1; 9.1)	0.04	3.1 (-1.3; 7.6)	0.17
Hip Abduction torque*	3.2 (-5.6; 12.1)	0.47		

Worst pain last week (NRS)	-3.7 (-5.0; -2.4)	<0.001	-4.1 (-5.4; -2.8)	<0.001
Sex*	2.0 (-4.7; 8.8)	0.55		
Diagnosis (OSD vs PFP)	6.0 (-1.1; 13.2)	0.10	9.34 (1.9; 16.8)	0.01

*Not included in multivariable model as they did not meet the p<0.15 threshold.
NRS: Number rating scale; OSD: Osgood Schlatter; PFP: Patellofemoral Pain.

Model 2: Association with KOOS sport/rec among adolescents with PFP	Unadjusted coefficient	p-value	Adjusted coefficient	p-value Adj coefficient
Knee extension torque*	1.7 (-3.4; 6.9)	0.50		
Hip Abduction torque*	2.9 (-6.5; 12.3)	0.55		
Hip Extension torque	12.5 (4.3; 20.7)	0.003	10.9 (3.7; 18.0)	0.003
Worst pain last week (NRS)	-4.2 (-5.6; -2.9)	<0.001	-4.2 (-5.5; -2.9)	<0.001
Sex	6.2 (-1.9; 14.4)	0.13	6.1 (-1.0; 13.3)	0.09

*Not included in multivariable model as they did not meet the p<0.15 threshold.
NRS: Number rating scale; PFP: Patellofemoral Pain

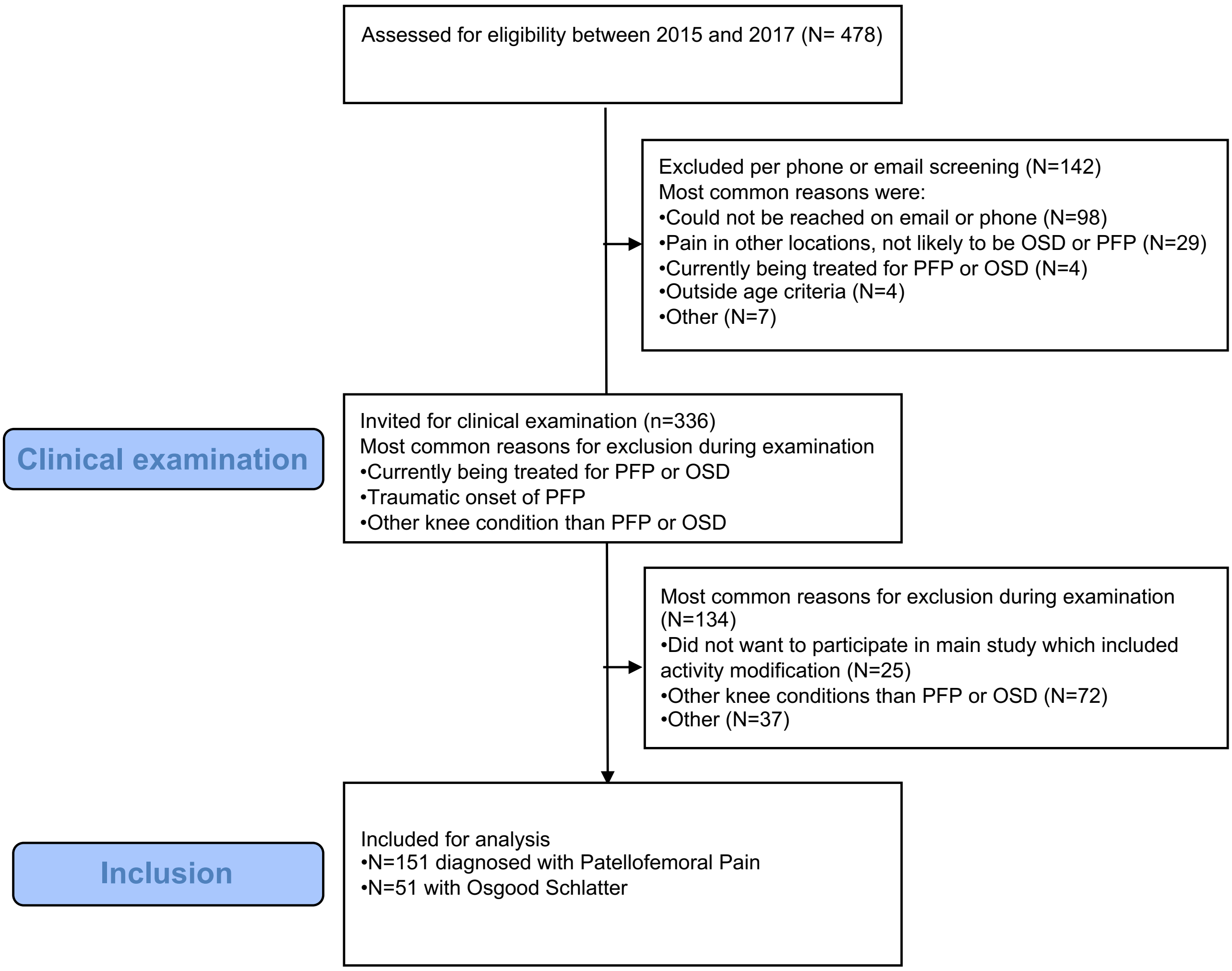

Figure 1: Flowchart

PFP; Patellofemoral pain. OSD; Osgood Schlatter.

Figure 2: Comparison of isometric hip and knee strength to controls among girls and boys with Osgood Schlatter (OSD) and Patellofemoral Pain (PFP). Data presented as mean + 95% CI. *Denotes statistically significant difference.